# Air Quality forecasting using a numerical weather prediction model: Potential sources of error

The University of Reading

**Helen Dacre, The University of Reading, UK (h.f.dacre@reading.ac.uk)**

## Introduction

The European Tracer Experiment (ETEX) evaluated the ability of long-range dispersion models to predict pollution concentrations across Europe. For the second tracer release, ETEX II, all of the models failed to simulate the transport of tracer released during the passage of a cold front and severely over-predicted surface concentrations.

It was hypothesised that the failure of the meteorological input data to represent the drop in wind speed and change in wind direction associated with the passage of the cold front let to a mis-prediction in the plume direction. In addition a failure to represent the frontal ascent and transport by convection led to an over-prediction of surface concentrations.

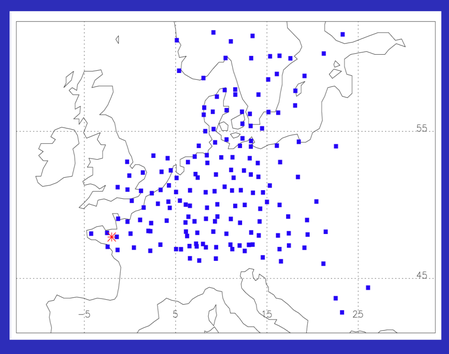
## Objective

The aim of this work is to assess the performance of the Met Office's NWP model in predicting tracer concentrations across Europe during ETEX II. Specific attention is paid to the representation of tracer transport by meteorological processes such as frontal flows and convection. The identification of potential sources of error when using an NWP model to produce air quality forecasts are also investigated.

## ETEX II Overview

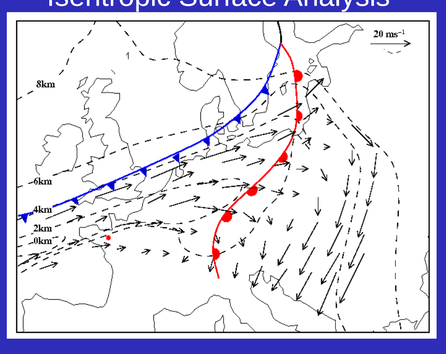
- A non-depositing, non-scavenged, non-reactive tracer was released from NW France into strong SW winds.
- The tracer release started at 15UTC on 14/11/94 and ended at 02:45UTC on 15/11/94.
- Tracer concentrations were measured for 48 hours at 168 sites.

Surface Measurement Sites



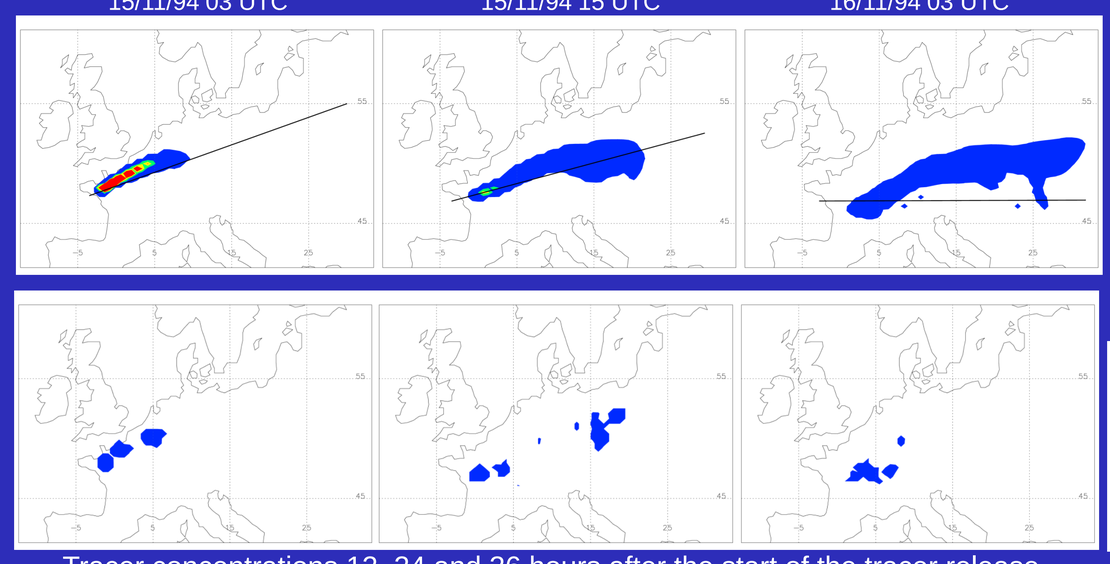
Modis visible 08UTC 14/11/94


Isentropic Surface Analysis




- The cold front associated with a mature low pressure system passed over the release site at 02UTC on 15/11/94.
- Moist isentropic flow on the $\theta_w$=287K surface relative to the frontal cyclone (arrows) and height of 287K surface (dashed contours) shows air ascending to heights of 4km in the warm conveyor belt.

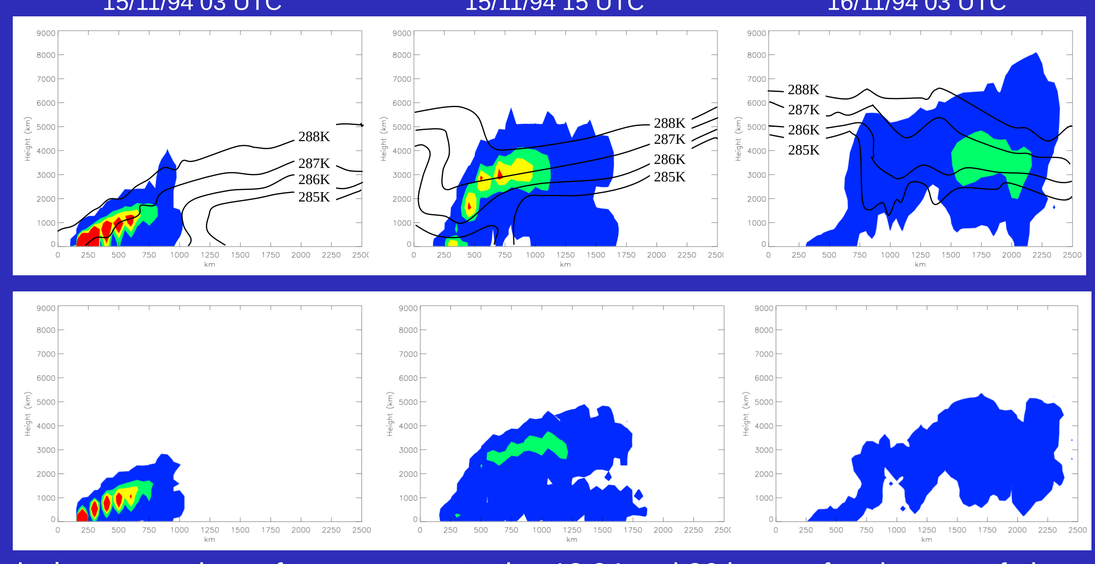
## Horizontal Tracer Transport




Tracer concentrations 12, 24 and 36 hours after the start of the tracer release , UM simulation at 20m (top) and observations (bottom)

- T+12: Modelled and observed tracer is rapidly transported NE by strong winds – model over-predicts surface concentrations.
- T+24: Tracer released behind the cold front is transported slowly eastwards – model over-prediction reduces
- T+36: Modelled and observed maximum tracer concentrations detected behind cold front – plume extends too far east.

## Vertical Tracer Transport

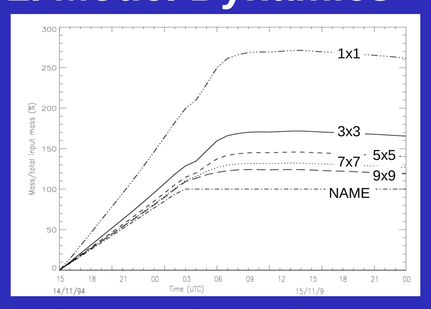



Vertical cross-sections of tracer concentration 12,24 and 36 hours after the start of the tracer release, over-plotted with wet-bulb potential temperature, UM (top), NAME (bottom)

- T+12: Tracer released ahead of the cold front ascends to height of 3km along the 287K moist isentrope in the warm conveyor belt.
- T+24: Tracer ascending in warm conveyor belt forms an elevated layer – tracer concentrations are larger in the UM than in NAME.
- T+36: Tracer released behind the cold front is trapped near the surface – vertical spread of tracer is larger in the UM than in NAME.

## Potential Source of Error in UM Simulation

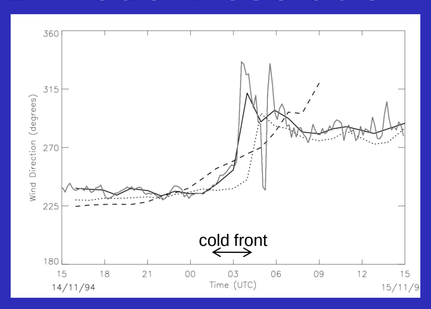
### 1. Model Dynamics




Total amount of tracer in the UM simulation. Tracer released over varying sized emission areas

- The UM does not conserve tracer.
- Non-conservation is due to interpolation in the semi-Lagrangian advection scheme combined with a positive-definite scheme which sets negative values of tracer to zero.
- Largest errors occur where gradients of tracer concentration are large, i.e. close to the source location.

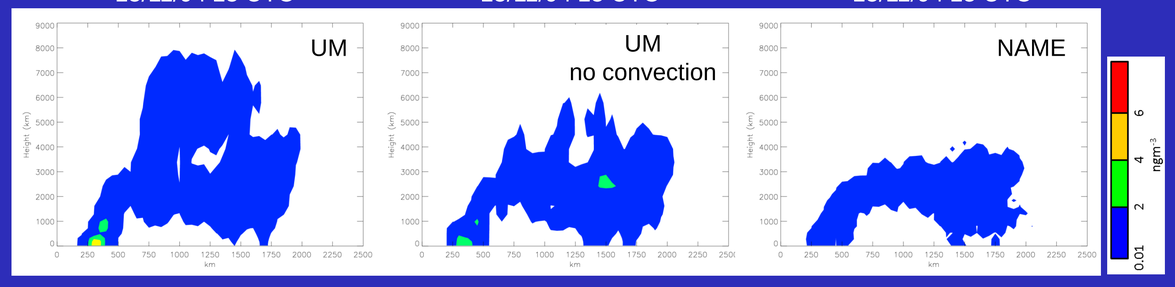
### 2. Model Resolution




Wind direction at release site. Observed (grey), 1-hour averaged obs (black), 50km UM (dashed), 12km UM (dotted)

- Observations: Wind direction changes rapidly as cold front passes over release site.
- 50km UM simulation: Wind direction change occurs over a 6 hour period – produces error in plume orientation.
- 12km UM simulation: Rapid wind direction change is captured but is delayed by 1 hour – produces error in location of max. tracer.

### 3. Model Physics




Vertical cross-sections of tracer concentration 24 hours after the start of the tracer release, UM simulation with convection (left), no convection (centre), NAME simulation (right)

- Convection transports tracer up to 8km in the 12km UM simulation.
- Turning off the convective mixing parameterisation reduces the vertical transport of tracer and produces a distribution similar to NAME.

## Conclusions

- During ETEX II a warm conveyor belt transported large amounts of tracer away from the surface up to a height of 4km. Convection further transported tracer to heights of 8km.
- The accuracy of UM predictions depends on the representation of the emission source and the meteorology associated with the cold front.